A Status Update for FLASHFlux including Data Usage Highlights from new POWER portal

Paul Stackhouse, David P. Kratz, and Takmeng Wong, (NASA LaRC)

PC Sawaengphokhai, Shashi Gupta and Anne Wilber (SSAI)

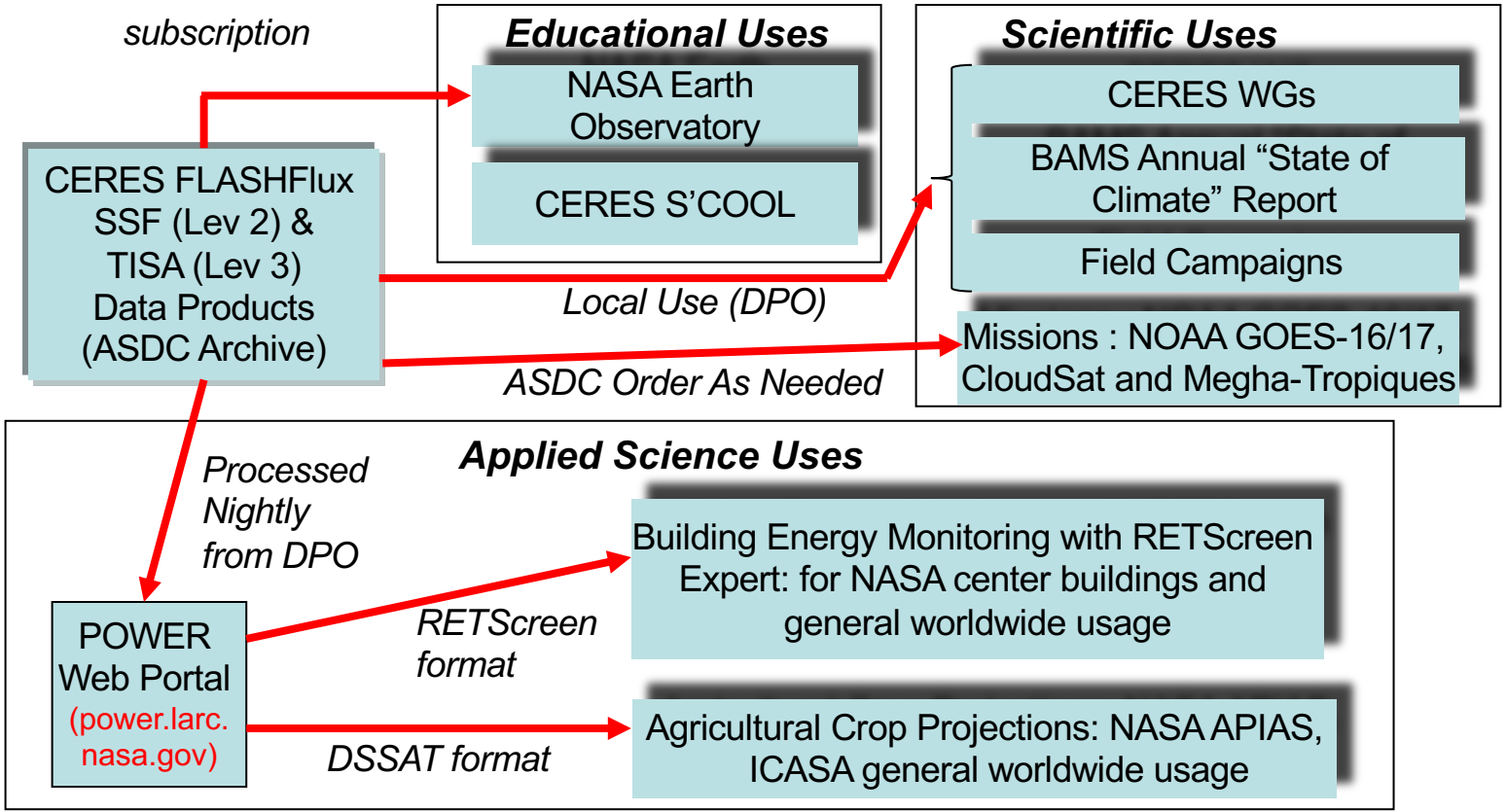
POWER Team: Jason Barnett, Tyler Bristow, and Bradley MacPherson (Booz-Allen-Hamilton); David Westberg and James Hoell, (SSAI)

Tonya Davenport and Fenny Wang and the Atmospheric Science Data Center Team (SSAI)

CERES FLASHFlux Overview

- ***FLASHFlux Overview***
  - Uses CERES based production system through inversion applied to Terra and Aqua for SSF products
  - Most recent calibration projected forward
  - LPSA/LPLA SOFA algorithms for surface fluxes
  - FF TISA uses a 3-day window for diurnal interpolation using both Terra and Aqua; central daily average delivered in sun local time
- ***FLASHFlux Operational Objectives***
  - FF SSF products within 4 days => ASDC, CERES subsetter
  - FF TISA Global 1x1 daily averages within 6-7 days latency => ASDC, CERES subsetter
  - FF TISA processed for inclusion into POWER Web portal to dissemination directly to users => most usage through POWER

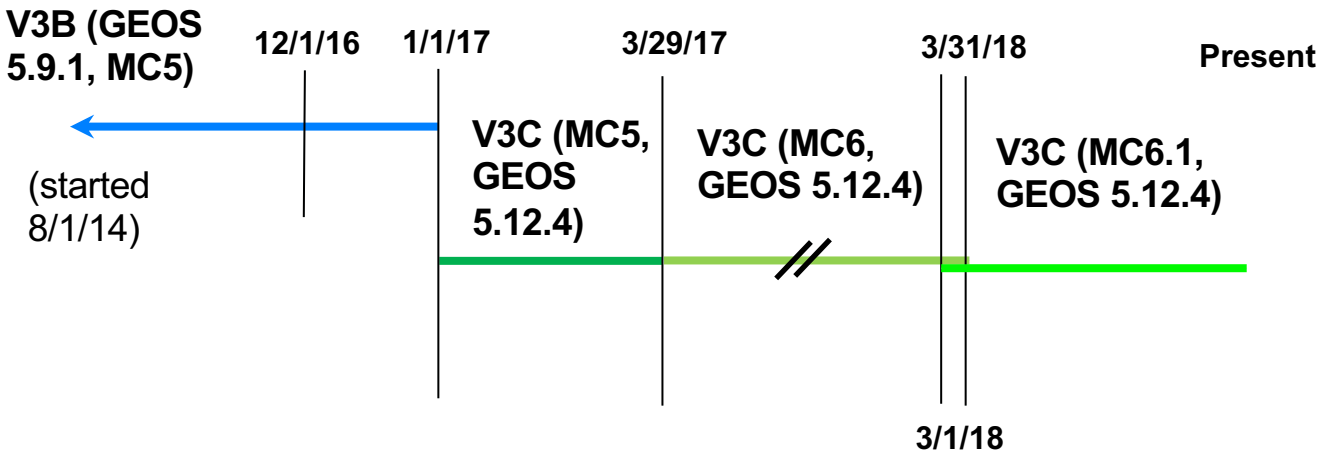
FLASHFLUX: Schematic of Current Uses



FLASHFlux v3C Status

- ***Production with v3C (MODIS C5/C6/C6.1) (since Jan 1, 2017)***
  - Now uses FP-IT (GEOS 5.12.4) and MODIS Collection 6.1 (after March 1, 2018)
  - FLASHFlux TISA available via CERES subsetter, ASDC and specialized formats through POWER web portal (power.larc.nasa.gov) 5-6 days latency
  - Plan to continue production for 2019 while production adapted to FF v4A; plan to reprocess from the end of December once FF v4A ready
- ***Current Activities***
  - Development towards V4A => V4A through FLASHFlux SSF being tested (uses MC6.1)
  - V3C vs 4A SSF; SW algorithm updates being evaluated
  - Finalizing V4A TISA modifications (consistent with Ed 4)
- ***FLASHFlux Data Provision Through POWER***
  - POWER web portal usage growing
  - Usage Examples from US and World
  - User metrics through April

Current FLASHFlux Versions

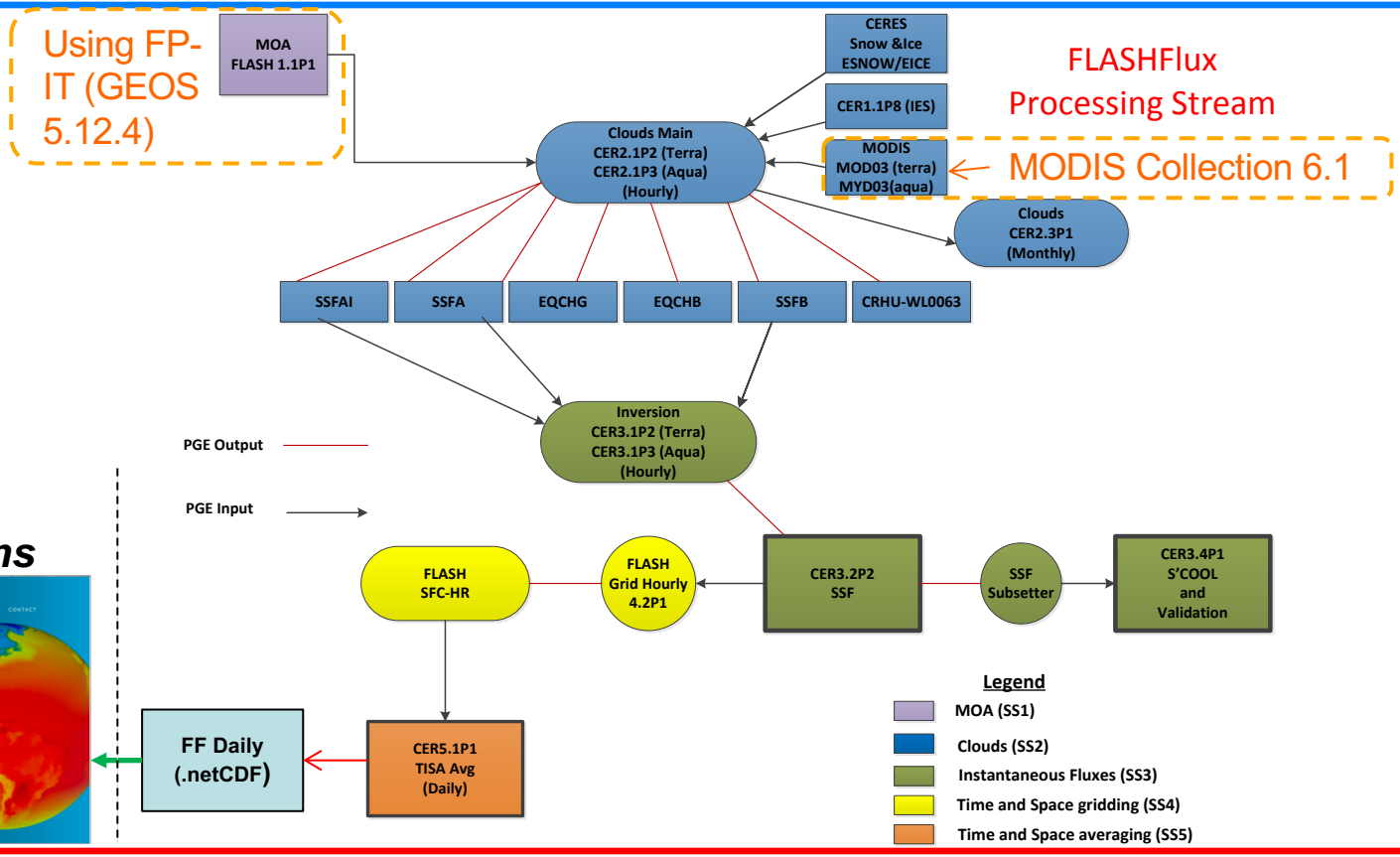


Using MODIS Collection 6 to 6.1 (but Ed 2 Clouds)

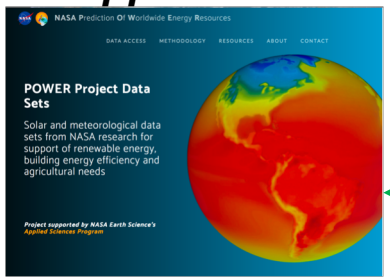
MC = MODIS Collection 5/6/6.1

GEOS = FP-IT version

Current v3C Production System

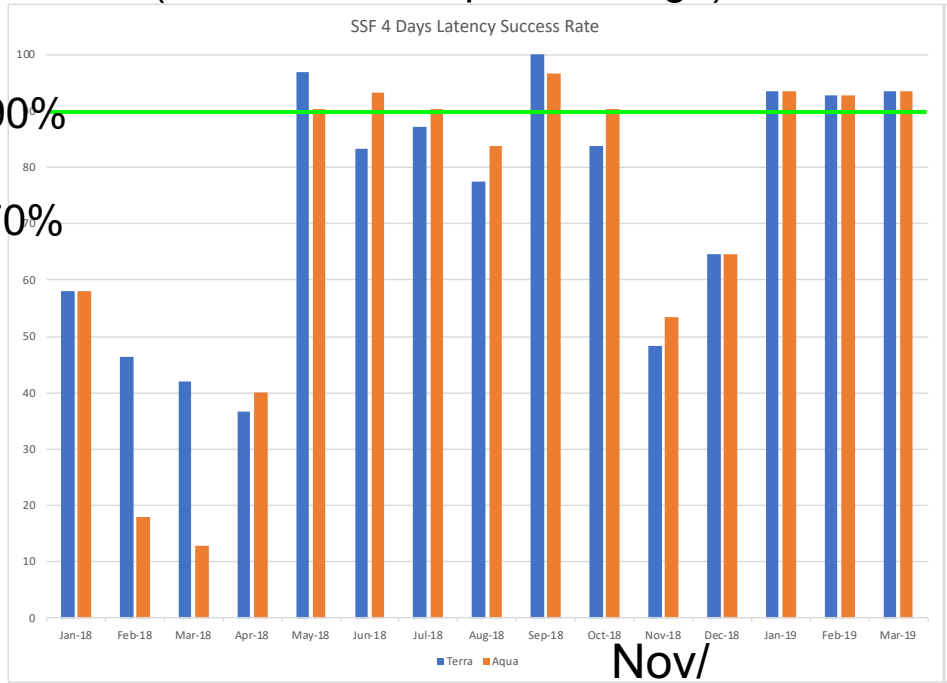


POWER Applications



Latency Success Rates for SSF and TISA

% Time SSF Products Delivered < 4 Days
(Terra in blue; Aqua in orange)

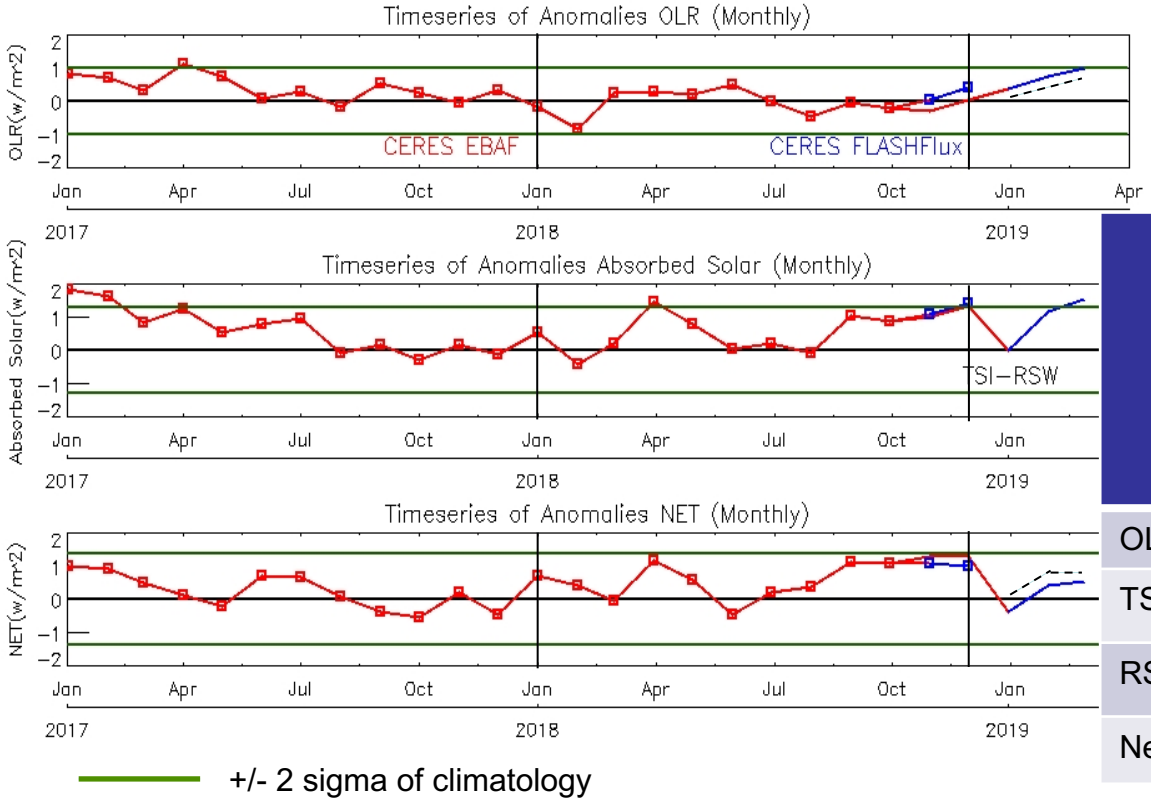


Nov/
Dec ‘18

% Time TISA Products Delivered < 4 Days
(6 days in blue; 7 days in red)

Nov/
Dec ‘18

Updated Global Anomaly Time Series



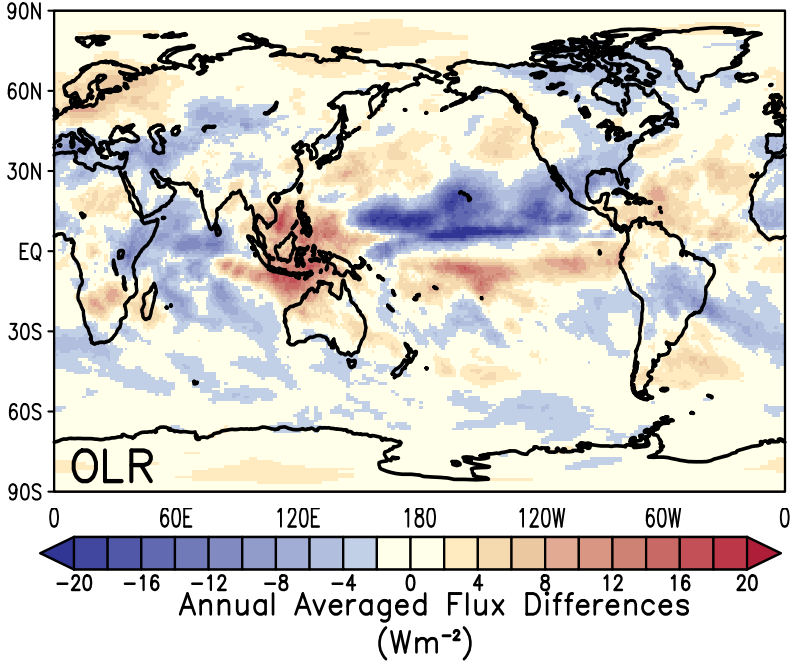
"State of the Climate 2018"
(Stackhouse et al, 2019 submitted)

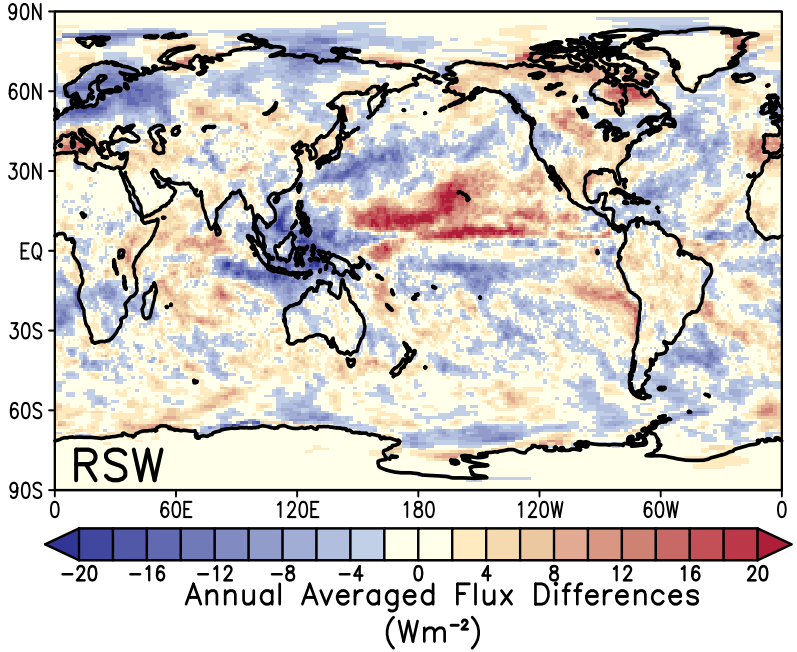
EBAF; extended with FF

	Global-annual Mean Difference (2018 minus 2017) (W m^{-2})	2018 Anomaly (relative to Clima-tology) (W m^{-2})	Inter-annual variability (2001 to 2017) (W m^{-2}) (2-sigma)
OLR	-0.40	+0.500	±0.60
TSI	-0.00	-0.10	±0.15
RSW	+0.05	-0.70	±0.85
Net	+0.40	+0.60	±0.80

TOA Flux Year-to-Year Changes

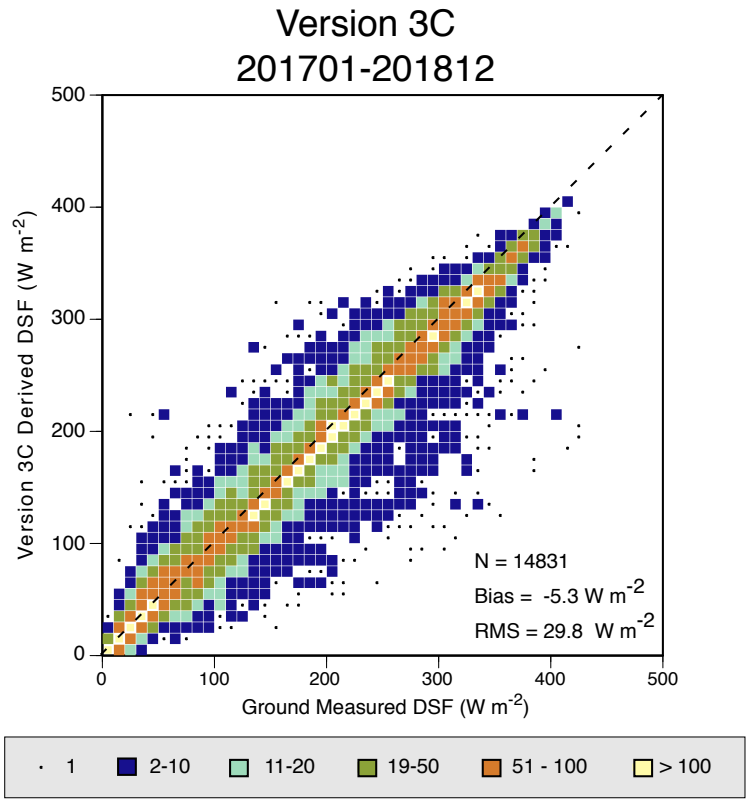
2018 (EBAF+FF') Minus 2017 (EBAF only)





Stackhouse et al, 2019 submitted

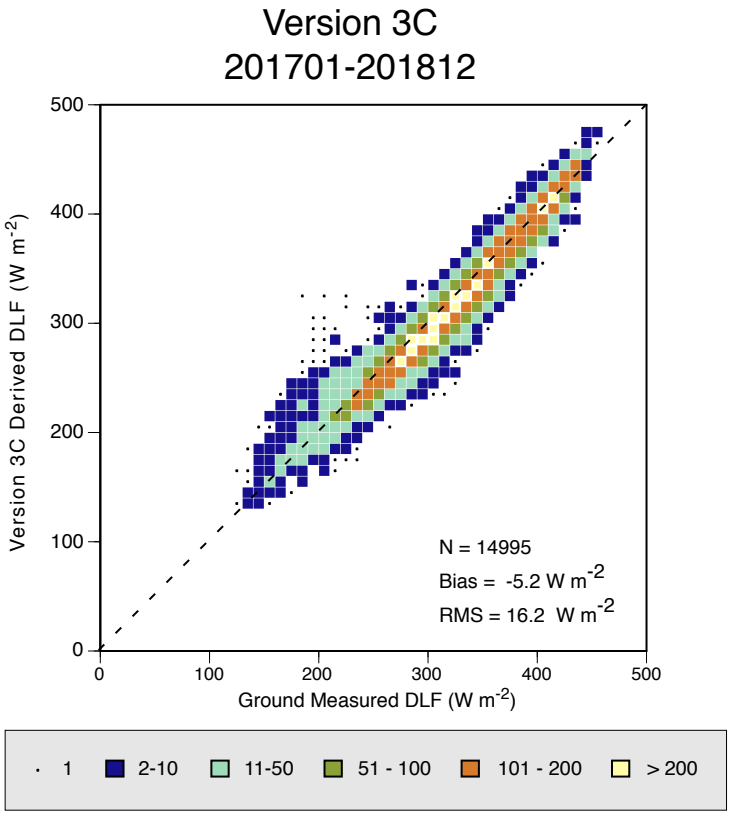
Recent SW Validation: 1/2017– 12/2018



Daily Averaged TISA Comparison

Ensemble Type	Bias ($W\ m^{-2}$)	RMS ($W\ m^{-2}$)	N
All Obs	-5.3	29.8	14831
Continental	-4.5	28.0	8311
Coastal	-3.6	25.5	2616
Desert	-5.0	20.7	2055
High Latitude	-25.4	54.8	1155
Island	11.4	30.1	694

Recent LW Validation: 1/2017 – 12/2018

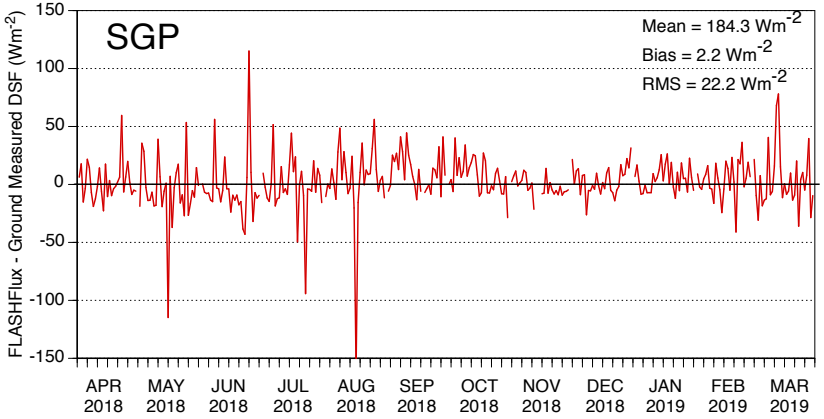


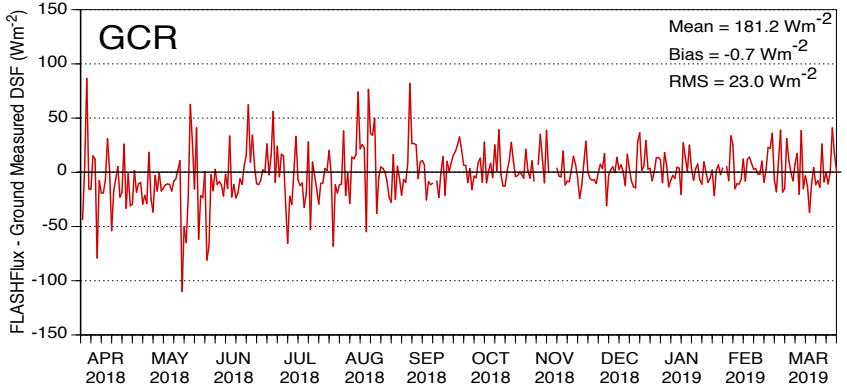
Daily Averaged TISA Comparison

Ensemble Type	Bias (W m^{-2})	RMS (W m^{-2})	N
All Obs	-5.2	16.2	14995
Continental	-7.8	16.5	8097
Coastal	-3.3	13.2	2599
Desert	-6.5	15.4	2025
High Latitude	6.9	21.2	1577
Island	-5.0	11.7	697

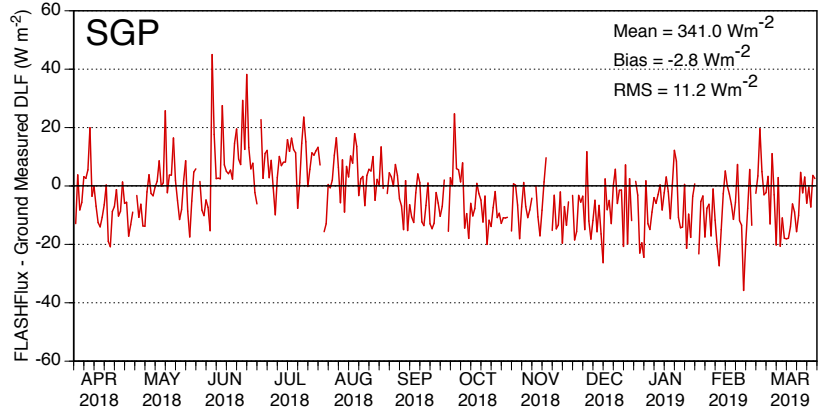
Version 3C Difference Time Series: SW & LW

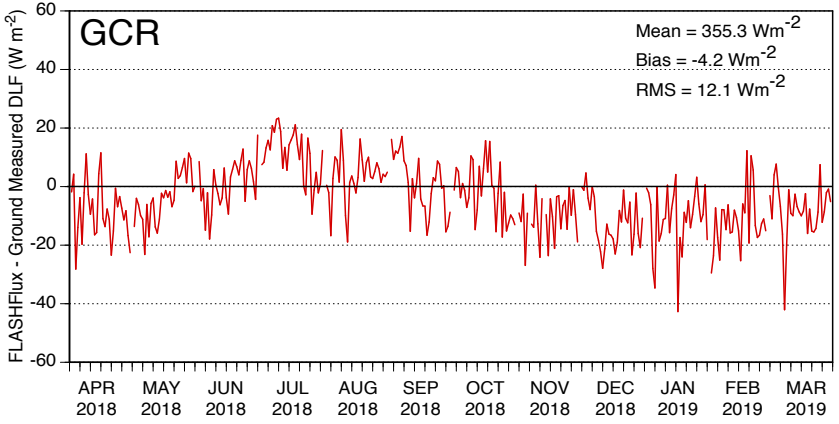
SW





LW



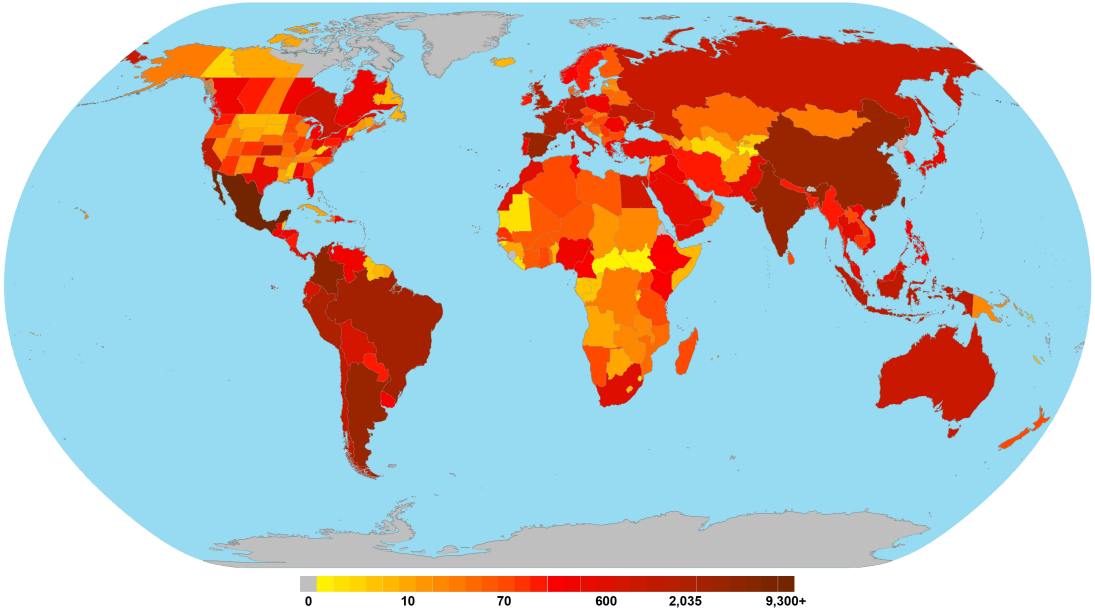


POWER GIS-Enabled Portal Featuring FLASHFlux Fluxes (https://power.larc.nasa.gov)

- **Using ArcGIS architecture** to geospatially enable entire POWER data archive for access to growing Applied Science users.
- **Increased spatial/temporal resolutions**:
  - Features CERES FLASHFLUX for Solar & GMAO MERRA-2/GEOS 5.12.4 for meteorological parameters
  - Mapped to ½ x ½ spatial resolution, Low latency Daily Time Series, 30 Year Climatological Averages
- ***Complete API service (data order using URL)***
  - allows for data to be repeatedly requested using a script or from within a user analysis program
- ***Interactive Data Access Viewer and ArcGIS Image Services***
  - User selection of location, parameters
  - Output formats ASCII, CSV, geoJSON, NetCDF4, ICASA, GeoTiff

POWER Data Usage Metrics Since Release

POWER CERES Unique Users May 16, 2018 to April 30, 2019



POWER Data Monthly Average Metrics
(POWER-GIS v1 on-line May 16, 2018)

Acquisition Type	Unique Users	Data Requests	Effective Volume (Gb)
API	18,491	27,315,190	11,966
ArcGIS	--[a]	85,413	0.01
DAV	73,987	478,378	1,363
OPeNDAP	136	669,208	216
RETScreen	1,606[b]	122,624	158
Total	**89,666[c]**	**28,670,813**	**13,703**
CERES	***64,015***	***14,791,195***	***3,045***
% CERES	***71.4%***	***51.9%***	***22.2%***

[a] *Currently untrackable;*
[b] *Old RETScreen version users not counted;*
[c] *Unique users across all acquisition types*

POWER Connects to RETScreen

RETScreen Clean Energy Management Software

World's leading clean energy decision-making software

- Benchmark, feasibility, performance and portfolio analysis
- Energy efficiency, heating and cooling, power generation and cogeneration
- Renewable energy and fossil fuels
- Residential and commercial/institutional buildings and industrial facilities
- 36 languages covering 2/3rds world's population

Empowering cleaner energy decisions worldwide

- 575,000+ users in all countries, growing at 50,000+ new users per year
- 1,100+ universities & colleges also use for teaching & research

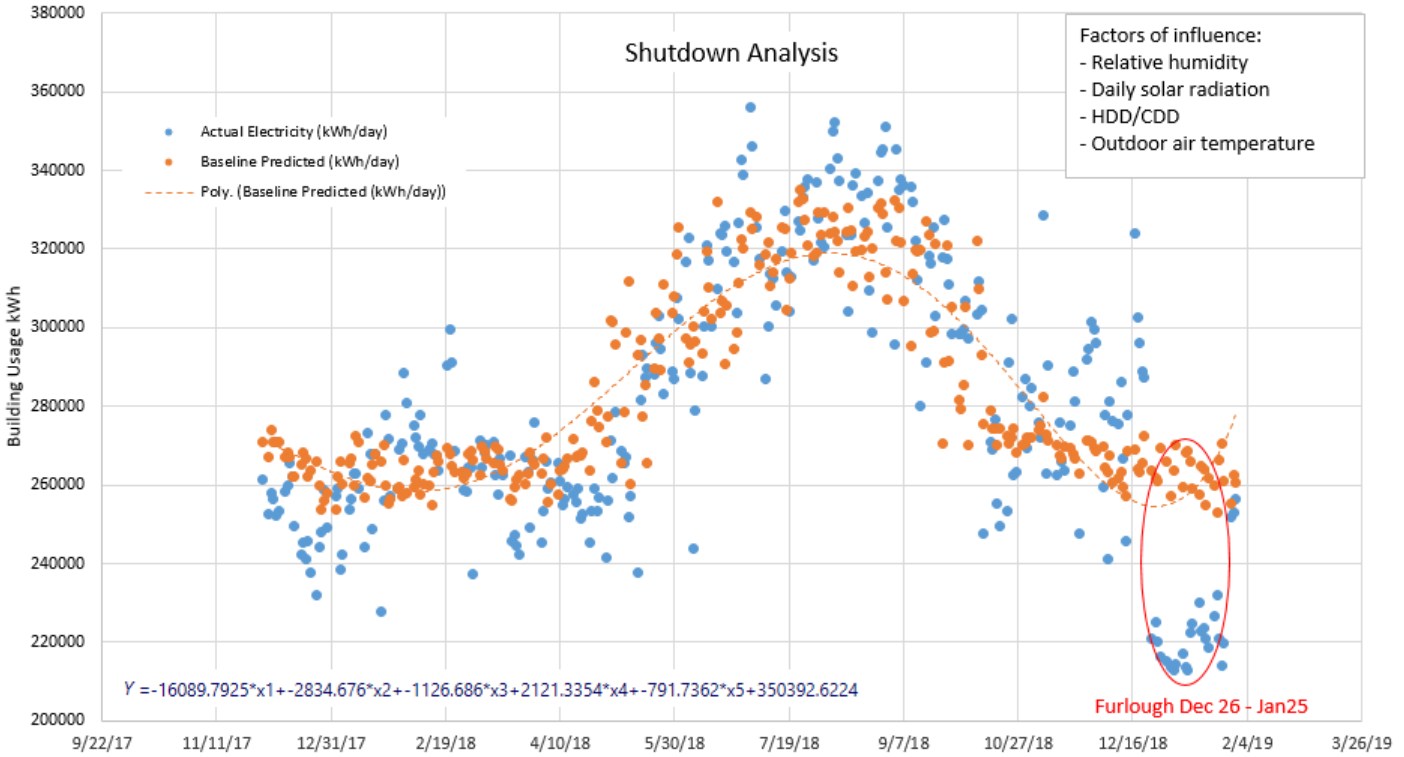
- Well over $8 billion in direct user savings since 1998

Next generation, *RETScreen Expert*, released September 2018 with updated NASA POWER interface

POWER Impacts: LaRC Energy Projects - RETScreen Shutdown Analysis

- "RETScreen is a great tool for analyzing discrepancies from the baseline."
- **Estimated 940,000 kWh ($61,000) reduction in usage during the furlough** as compared to what the predicted usage should have been (relative to weather).
- How was this reduction realized?
  - Partial building shutdown.
  - Significantly fewer people on Center (estimated ~400 total; about 11%).
- ***NASA Office of Strategic Infrastructure is planning to use RETScreen and Autotune (based upon EnergyPlus model) NASA wide.***

Courtesy Loretta Kelemen, Director, LaRC Center Operations



POWER Impacts: Benefits for World Agriculture

S. America/Italy: HCO Hazelnut Company (Ferrero Corp. – makers of Nutella) uses data to assess suitability of crops in different regions; then uses for crop modeling simulations

U.K.: "I am a researcher at ICRAF HQ (World Agroforestry Centre) trying to use POWER data in R to test the climate resilience of different farming methods in Africa." *Peter Steward, School of Biology, University of Leeds, Leeds.*

Australia: " … I can't think of any other way I would do ET-based irrigation scheduling for sites that do not have actual daily records if it weren't for the NASA data, so the service is invaluable for that work" Dr. John McPhee, Tasmania Institute of Agriculture

Germany: Assess physical and chemical effects of land management practices. *J Oanneum Research Forschungsgesellschaft mbH LIFE – Centre for Climate, Energy and Society, Graz*

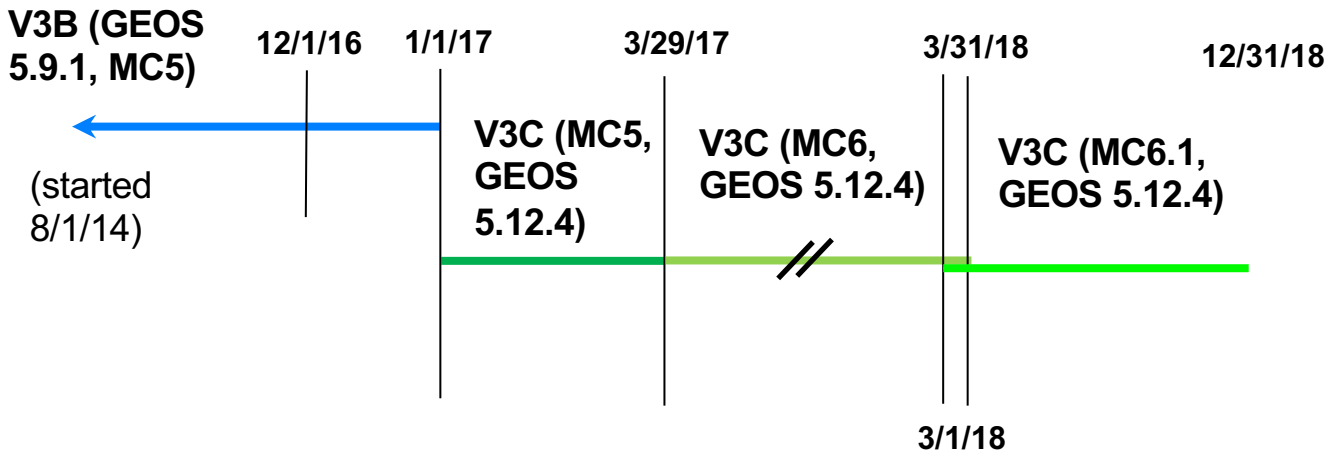
US/Netherlands: Worked with POWER data extensively for crops models in the global yield gap atlas project www.yieldgap.org

US: Lumigrow is developing tool that may use POWER solar information from API to design smart lighting systems for greenhouse horticulture. Expects to build to 2000-3000 users per month. *Brandon Newkirk, Emeryville, California, USA*

Near Future: Moving FLASHFlux Toward V4

Attribute	FF v3C (MC6)	FF v4A	FF v4B
Baseline 1QC	Previous	New calibration	New calibration
GEOS FP-IT input	GEOS 5.12.4	GEOS 5.12.4	GEOS 5.12.4
MOA	Ed 4 compatible	Ed 4 compatible	Ed 4 compatible
MODIS	Collection 6	Collection 6.1	Collection 6.1
Clouds	Ed 2	Ed 4 w/ MC 6.1 calibration (current work)	Ed 4
SIBi (Snow/ICE Brightness Index)	No	Yes	Yes
Inversion (improved ADMs)	Ed 2	Ed 4	Ed 4
Aerosols	MATCH climatology	MATCH climatology	GEOS 5.12.4
Flux Algorithms	Unchanged	Modified SW surface algorithm (current work)	A0, Ap adjustments; new clear-sky TOA & surface albedos (current work)
TISA	Ed 2	Compatible w/ Ed 4 (current work)	Compatible w/ Ed 4 (custom CERES TSI?)
Data Processed	March 28 - present	Planned to begin 1/1/19	None
Validation Results	1/1/17 – 6/30/18	---	---

Moving to FLASHFlux Ed4A



1/1/19

Under development and testing

V4A (CERES Ed 4, MC6.1, GMAO 5.12.4)

MC = MODIS Collection 5/6/6.1

GEOS = FP-IT version

Planned v4A Production System

Initial data date Jan 1, 2018

Update for Ed 4 using FPIT

MOA FLASH 1.1P1

Ed 4 Clouds

CERES Snow &Ice ESNOW/EICE

CER1.1P8 (IES)

Clouds Main CER2.1P2 (Terra) CER2.1P3 (Aqua) (Hourly)

MODIS MOD03 (terra) MYD03(aqua)

FLASHFlux Processing Stream

MODIS Collection 6.1

Clouds CER2.3P1 (Monthly)

SSFAI | SSFA | EQCHG | EQCHB | SSFB | CRHU-WL0063

SIBI

Inversion CER3.1P2 (Terra) CER3.1P3 (Aqua) (Hourly)

PGE Output

PGE Input

FLASH SFC-HR

FLASH Grid Hourly 4.2P1

CER3.2P2 SSF

SSF Subsetter

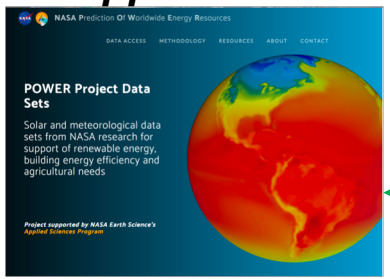
CER3.4P1 S'COOL and Validation

Update for Ed 4 SSF

CER5.1P1 TISA Avg (Daily)

FF Daily (.netCDF)

POWER Applications



Legend

- MOA (SS1)
- Clouds (SS2)
- Instantaneous Fluxes (SS3)
- Time and Space gridding (SS4)
- Time and Space averaging (SS5)

Summary and Conclusions

- ***FLASHFlux 3C and 4A progress***
  - Continued producing v3C MODIS 6.1
  - Developing v4A compatible with CERES Ed 4; will use to MODIS Collection 6.1
  - Evaluating changes to SW MODEL B
- ***FLASHFlux Applications:***
  - POWER web portal featuring GIS tools for CERES/FF/POWER and with ASDC to resulted in expansion of user base >64K unique IPs and ~15M data requests
  - Building agricultural usage; account for nearly 75% of data volume
- ***FLASHFlux publications:***
  - 2018 SotC report submitted
  - Future papers: FLASHFlux TISA applications including energy
- ***Future Versions***
  - Developing v4A by migrating CERES Ed 4 Clouds (collection 6.1) and Inversion; must adapt current FF TISA => target June ‘19
  - Longer-term Upgrades (Spring ‘20): Refine SW Model B, Assess & adapt CERES TSI to FLASHFlux TISA, Assess FPIT aerosol assimilation; NPP SSF

FLASHFlux Web Sites:

https://flashflux.larc.nasa.gov

https://power.nasa.gov & https://power.nasa.gov

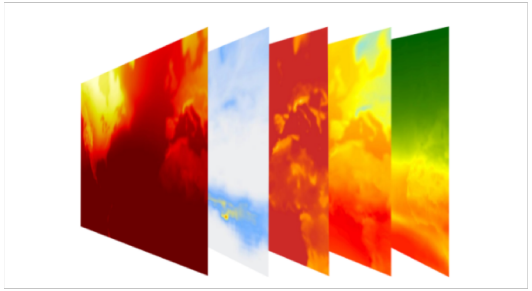
Extras

POWER (v1, GIS): Three Main Data Accessibility Options

Data Access Viewer

Responsive web mapping application providing data subsetting, charting, and visualization tools in an easy-to-use interface.

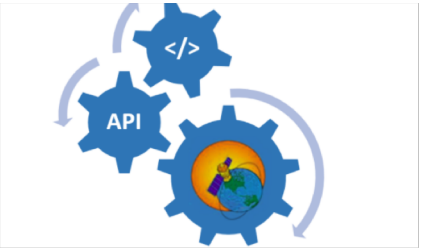
POWER DATA ACCESS VIEWER



ArcGIS Image Services

GIS-Ready Time-Enabled ArcGIS Image Services for mapping, visualization, and spatial analysis.

POWER DATA ACCESS VIEWER



POWER API Integration

Access the POWER data holdings through your own custom scripts and scalable applications.

POWER API DOCUMENTATION

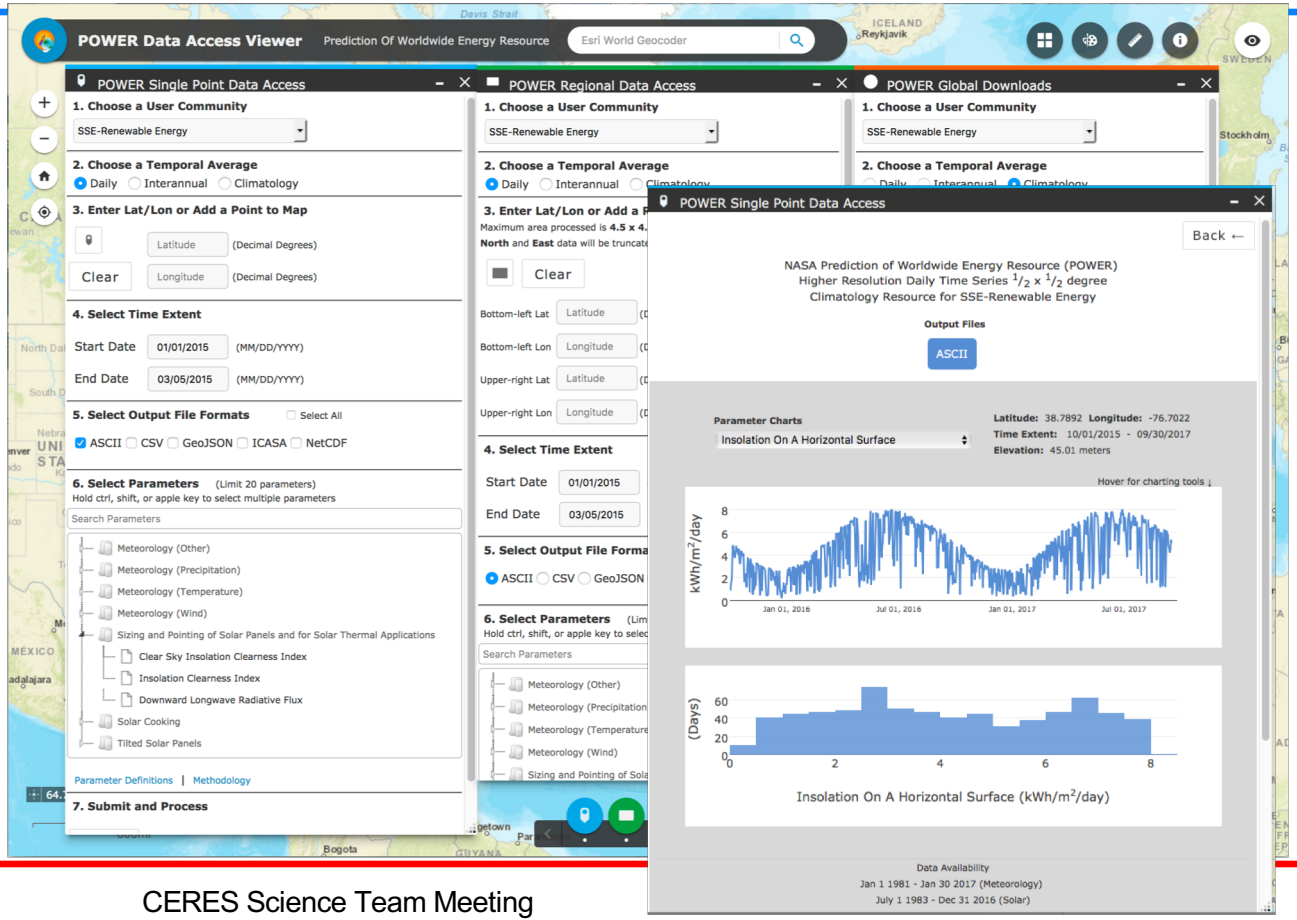
POWER (v1, GIS): Interactive Data Access Viewer

Graphical Data Access

- ½ x ½ deg; within 5-7 days of obs
- multiple parameters from FLASHFlux, GMAO, etc. available
- parameters arranged by application community (i.e., renewable energy, buildings, agroclimatology)
- Multiple data output formats

Four Applications :

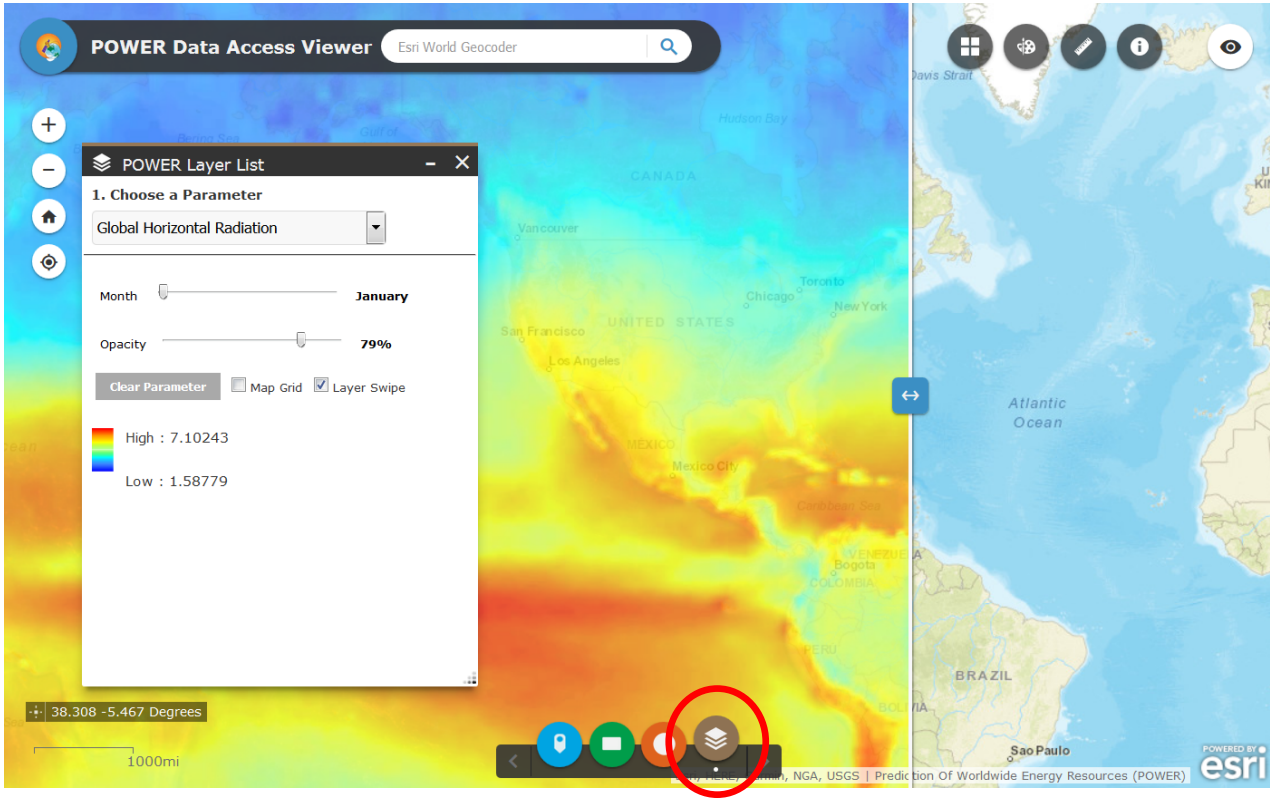
- Time series at a single point (daily, monthly, up to 30 years*)
- Regional times series (limited area)
- Global climatology (30 year*)
- Layer List (Image Services)



POWER (v1, GIS): ArcGIS Image Services

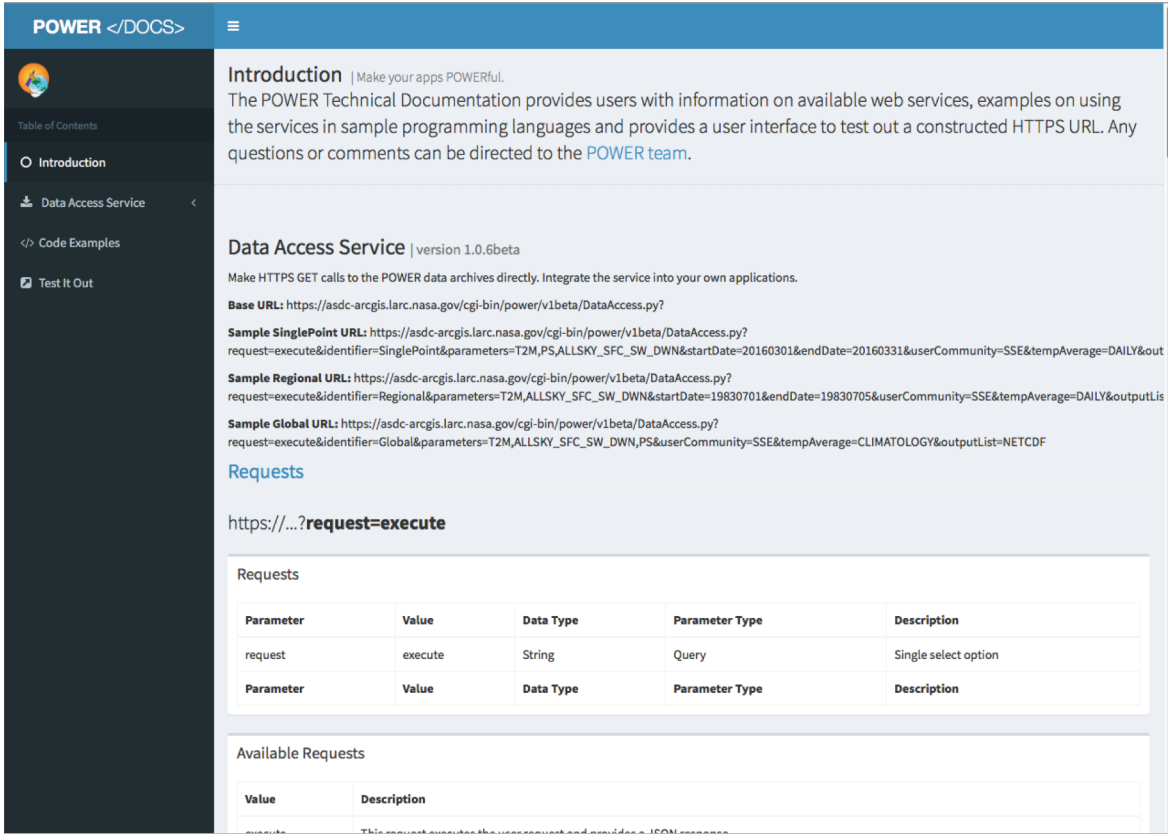
Image Services

1. Migrated current SSE-GIS capabilities (see https://asdc-arcgis.larc.nasa.gov/sse/
2. OGC compliant (opensource)
3. Includes all available parameters for climatological values (ability to click a location and obtain data values)
4. Background maps with support for image tools
5. Time series slider and swiping tools, etc.
6. To Do: implement more services, allow for time series, add on-the-fly



POWER (v1, GIS): Accessing Data with API Service

- Complete instructions to setup up URL based data access (API using OPeNDAP)
- Provide immediate access to the data parameters and time periods required
- Returned file formatted for general software (Excel, GRaDs, MatLab) or customized script/coding for Decision Support Tools (RETScreen, HOMER)

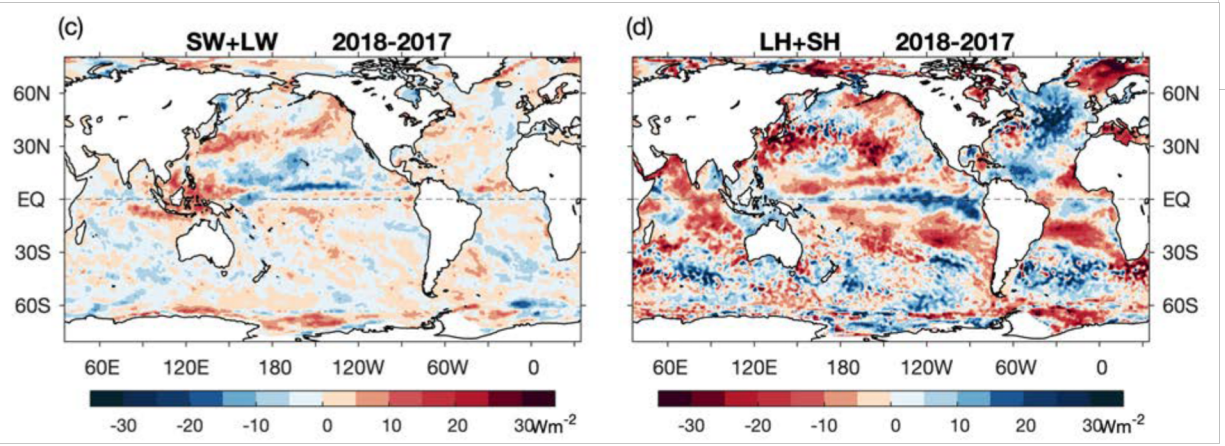


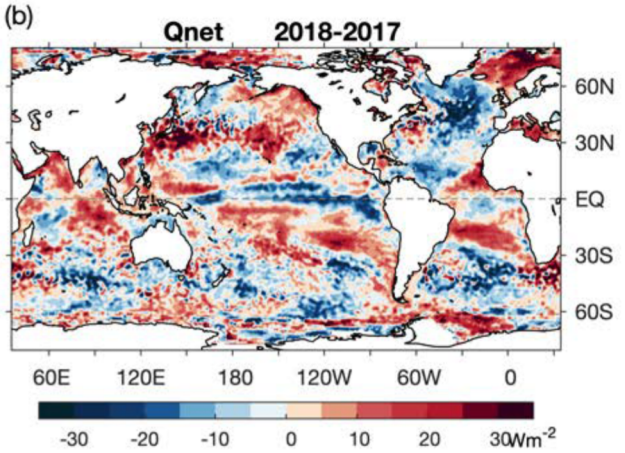
Surface Energy Flux Year-to-Year Changes

Yu et al., 2019 submitted to State of Climate total surface energy changes 2018 - 2017l

$$Qnet = (SW_{net}+LW_{net}) – (LH+SH)$$

- FF provides last 2 years of surface fluxes for SW and LW
- Changes consistent with TOA
- LH, SH using OAFlux

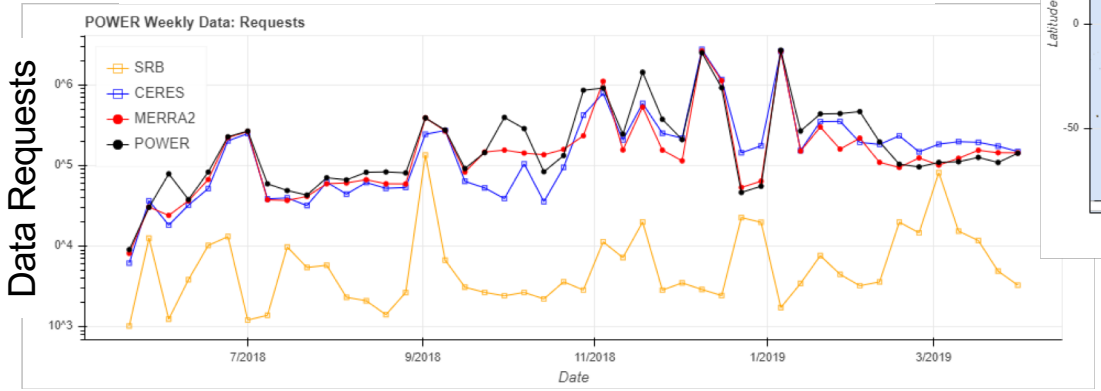


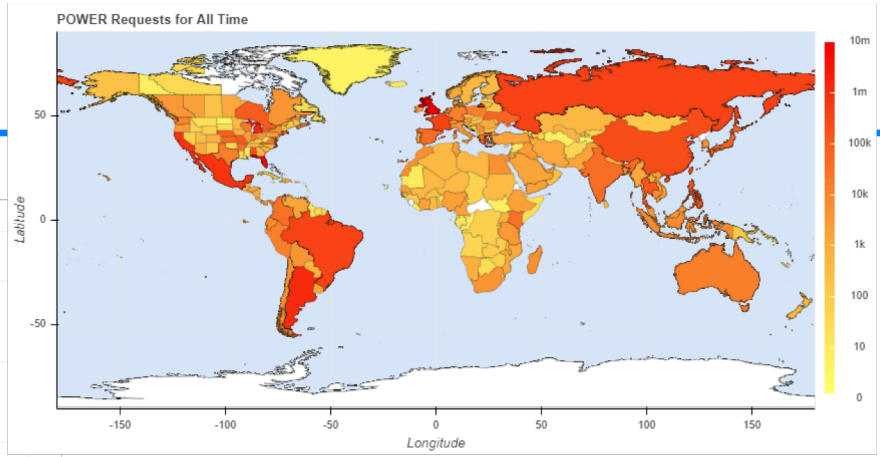


- LH, SH interannual changes larger than net SW+LW
- El Nino like changes in central Pacific & warming in N. Pacific

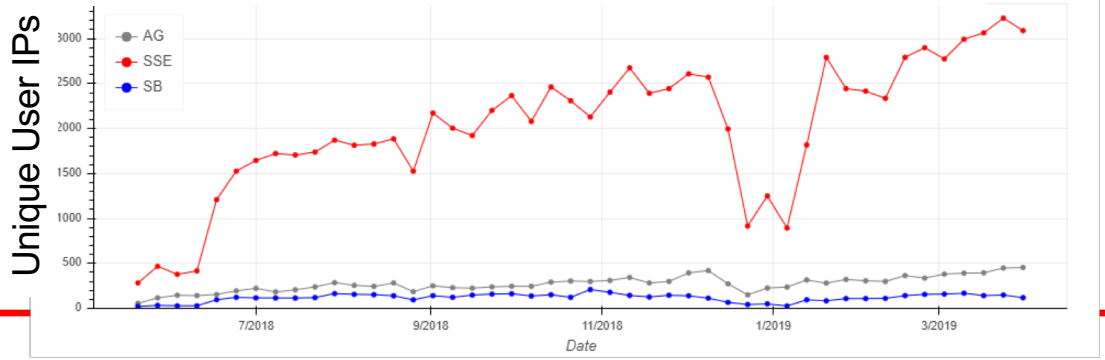
POWER Impacts: User Metrics

POWER Weekly Data Requests by Data Source





POWER Weekly User Unique IPs by User Community



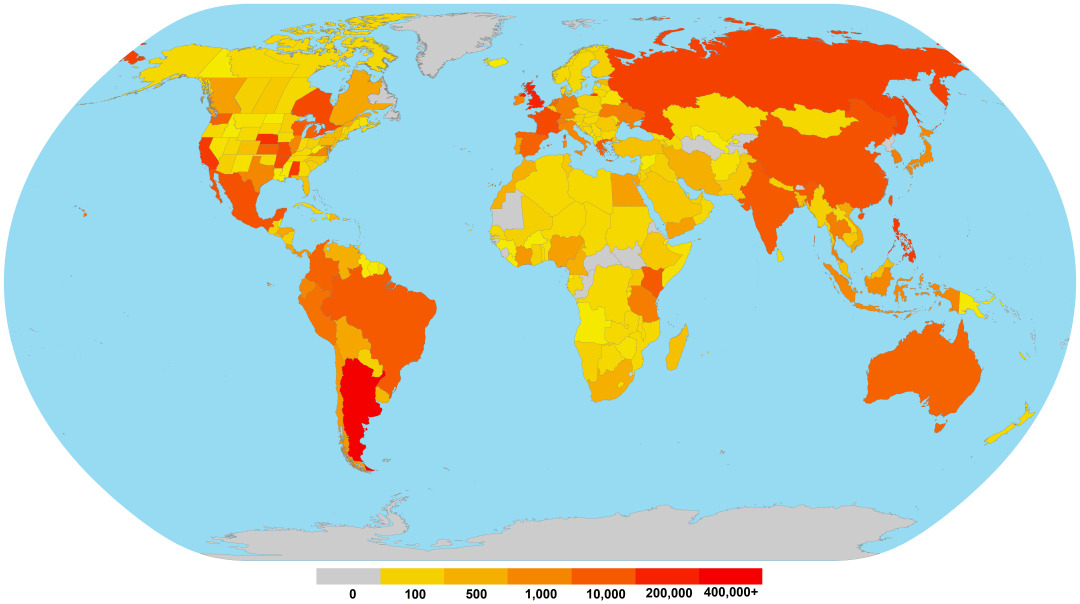
Inception through 3/31	Unique Users (K)	Data Requests (M)	Data Volume (Gb)
Renewable Energy	71.3	5.76	2543
Sustainable Buildings	5.8	0.86	270
Agro-climatology	9.3	19.44	9,340
Total	**78.5***	**25.95**	**12,032**

Low latency 27% of DAV; 73% of daily API

** Total excludes user requests under different them*

POWER User Metrics Since Release

POWER Data Requests May 16, 2018 to August 31, 2018



POWER Data Request Metrics
(POWER-GIS v1 on-line May 16, 2018)

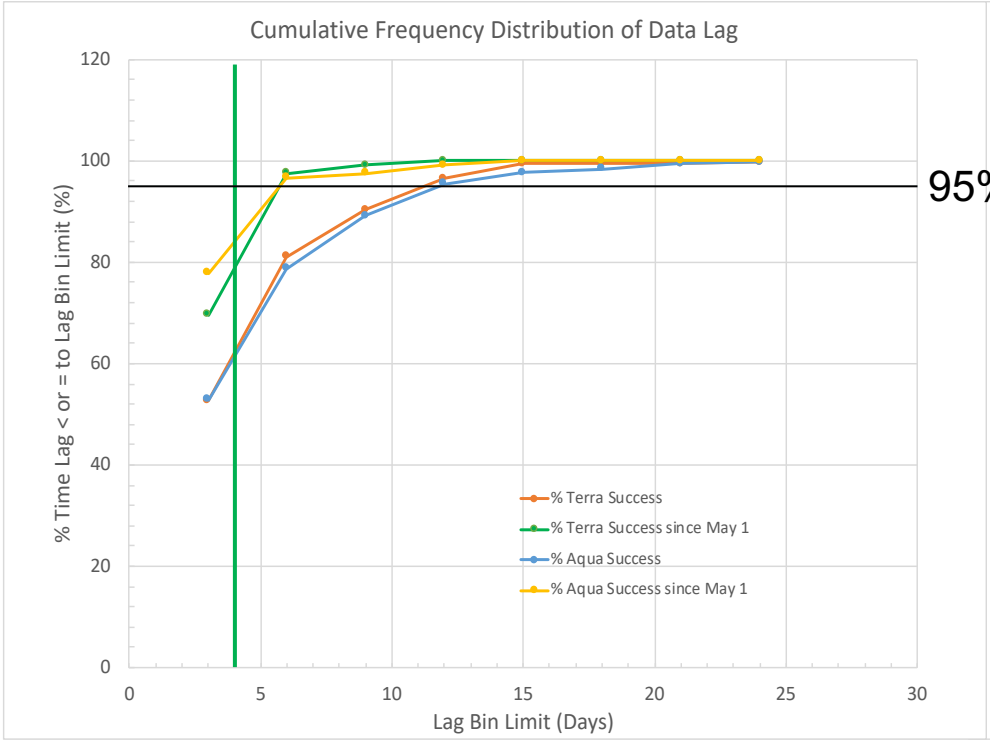
Month	Unique Users	Data Requests	Effective Volume (Gb)
May[+]	1,074	148,090	87
June	4,787	695,524	412
July	7,688	310,585	234
August	7,985	519,756	673
Total	**19,706***	**1,673,955**	**1,407.09**
% Using FLASHFlux	71.3%	64.6%	14%

[+] *Includes only May 16 – May 31*

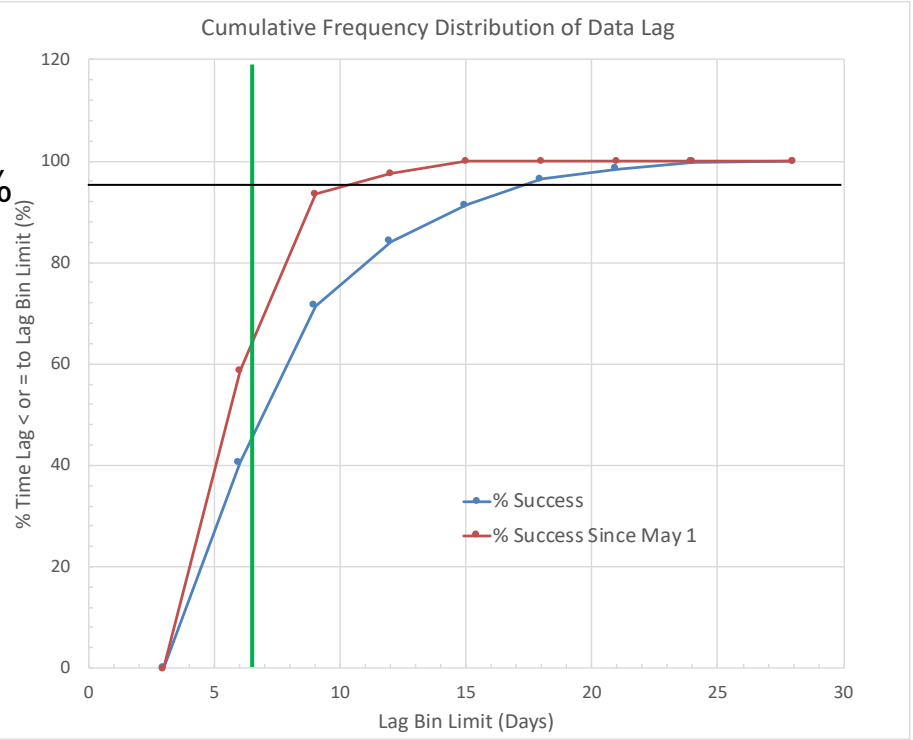
* *Excludes returning users in multiple months*

FLASHFlux Latency Success

FF SSF Goal: 4-day latency



FF TISA Goal: 6-day latency

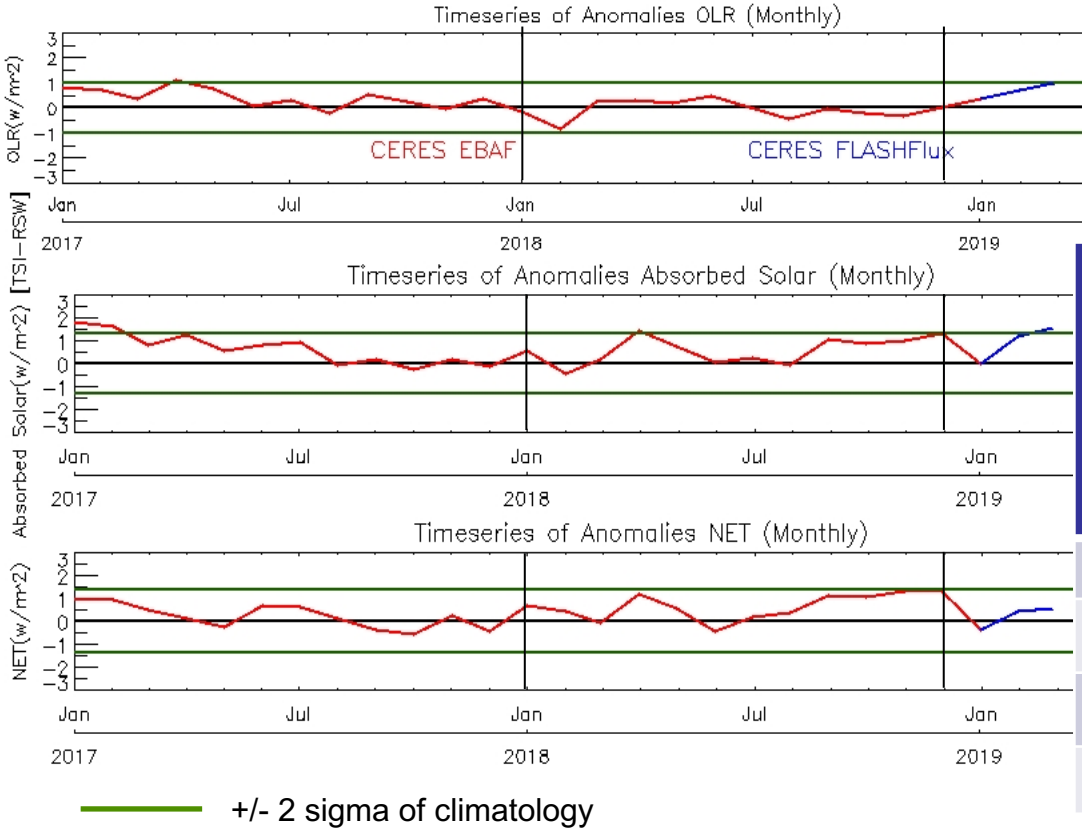


Example Uses of FF Data Distributed Through POWER

- *3M Company manages 11 facilities using RETScreen and POWER (CERES FLASHFlux) data: "The NASA datasets we use are critical to our energy analysis since they are used as major variables that predict our energy use."*
- *Renewable energy engineers use daily solar irradiance to assess performance of multiple solar systems for clients of RETScreen users in Ottawa region (e.g., others include MIT, Lockheed Martin, Corning, Johnson Controls)*
- *Hawaii Department of Education implementing program to use RETScreen at all education buildings/schools*
- *Ontario Schools including Niagara district using RETScreen (https://www.linkedin.com/pulse/school-board-energy-managers-lead-way-gregory-j-leng)*

District School Board of Niagara's Main Office

Updated Global Anomaly Time Series

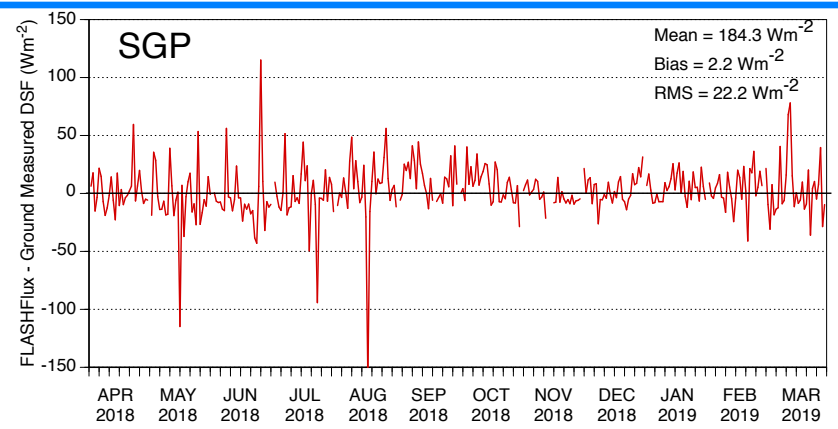


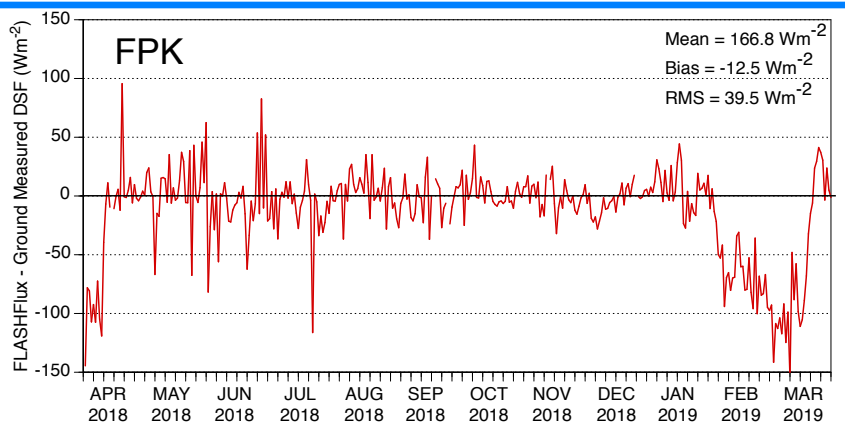
"State of the Climate 2018"
(Stackhouse et al, 2019 submitted)

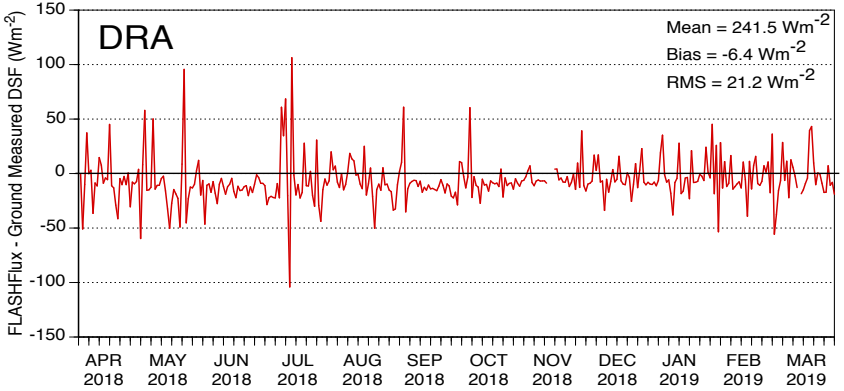
EBAF; FF extending

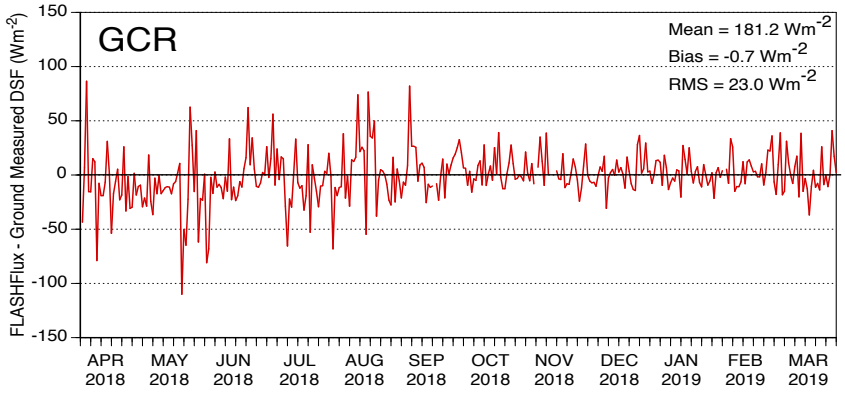
	Global-annual Mean Difference (2018 minus 2017) (W m^{-2})	2018 Anomaly (relative to Clima-tology) (W m^{-2})	Inter-annual variability (2001 to 2017) (W m^{-2}) (2-sigma)
OLR	-0.40	+0.500	±0.60
TSI	-0.00	-0.10	±0.15
RSW	+0.05	-0.70	±0.85
Net	+0.40	+0.60	±0.80

Version 3C Difference Time Series: SW









Version3C Difference Time Series: LW